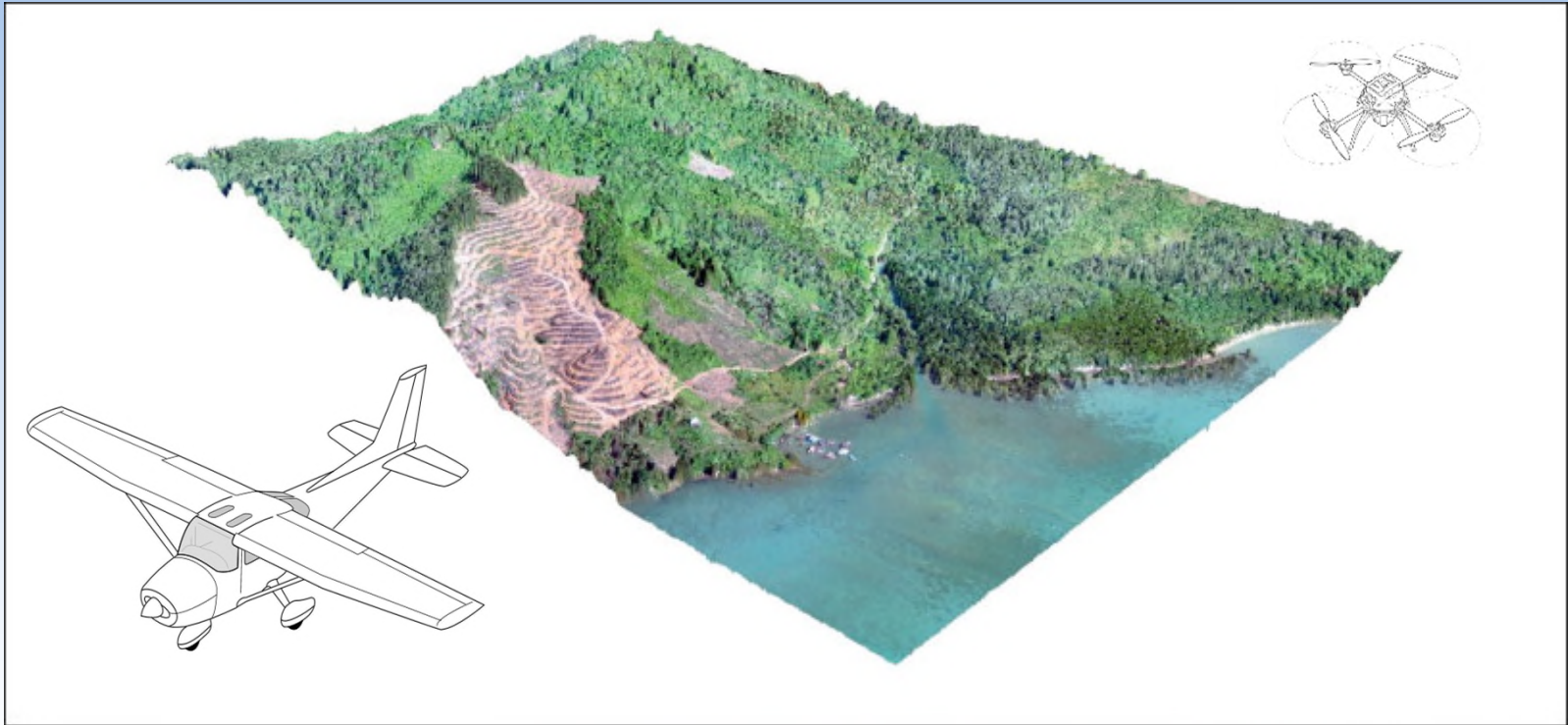


Use of Aircraft & UAV Remote Sensing to Screen for HABs in Fresh & Marine Waters of NJ



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New Jersey Department of Environmental Protection
Division of Water Monitoring & Standards
Bureau of Freshwater & Biological Monitoring
Bureau of Marine Water Monitoring



Overview

1. Marine Water

- Remote sensing of chlorophyll 'a' via manned aircraft
- Example of a NJ Marine HAB response

2. Freshwater

- Current NJ freshwater HAB response strategy
- Remote sensing of phycocyanin via manned aircraft

3. Unmanned Aerial Vehicle (UAV or drone)

Algal Blooms and Human Health

- Harmful algal blooms (HABs) can occur in both freshwater and marine environments.
- HABs produce toxins which can cause adverse health effects in humans and animals through contact or ingestion
- Toxins produced by marine algal blooms can have a negative impact on ecosystems by causing low dissolved oxygen, various tide colors, fish kills and shellfish contamination.



Major Marine HAB Species - East Coast

- **Paralytic Shellfish Poisoning (PSP)**

Alexandrium spp. – Currently found from Maine to Long Island

- **Neurotoxic Shellfish Poisoning (NSP)**

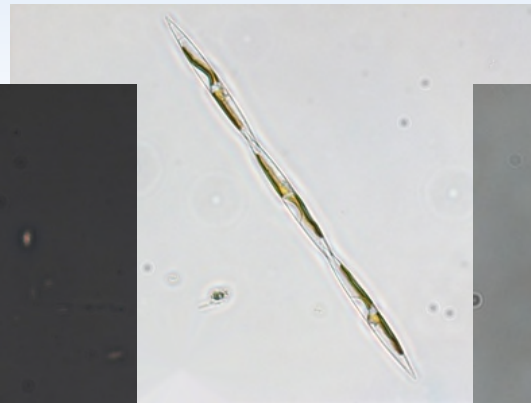
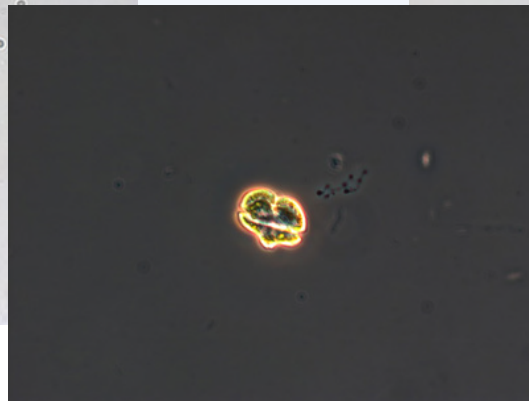
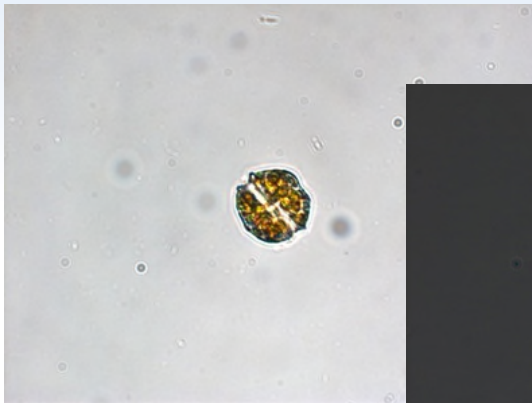
Karenia brevis – Found from Delaware to Florida

- **Amnesic Shellfish Poisoning (ASP)**

Pseudonitzschia seriata – East Coast, typically not in blooms

- **Diarrhetic Shellfish Poisoning (DSP)**

Dinophysis spp. & *Prorocentrum lima* - East Coast, typically not in blooms.

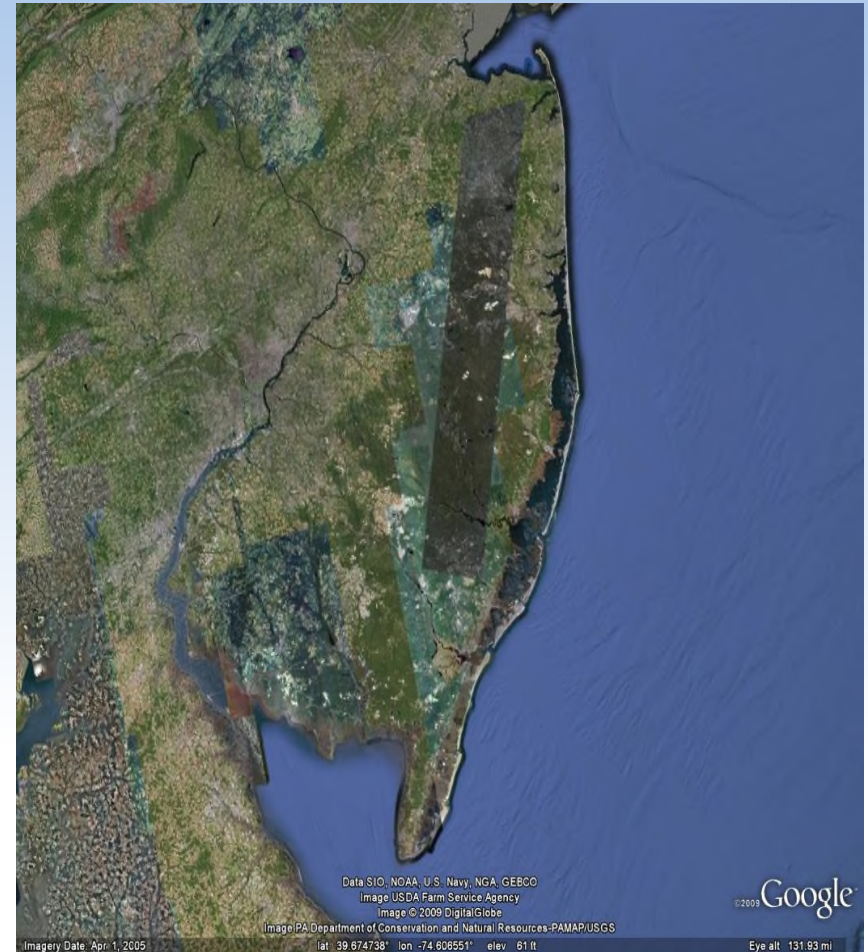


Photos:

<http://oceandatacenter.ucsc.edu/PhytoGallery/phytolist.html>

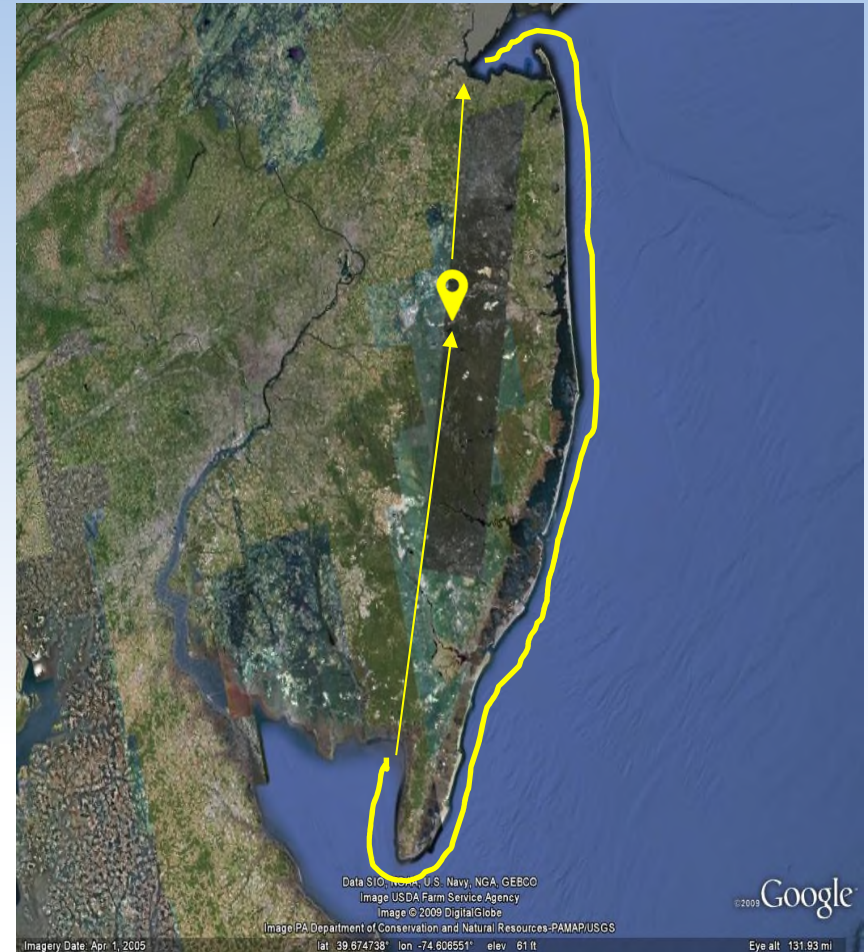
HAB Monitoring of New Jersey's Coast

- Aerial flights monitor ~120 miles of coastline and flown by the NJDEP Forest First Service plane.
- To protect the Public, monitoring must be able to cover entire state on a routine basis.
- Coastal Surveillance Flights are flown to monitor floatables.
- In 2007, hyperspectral sensor was added to the plane for remote sensing of Chlorophyll 'a' to monitor for algal blooms.
- Uses a local algorithm developed by NJDEP Bureau of Marine Water Monitoring.



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Coastal Monitoring via Remote Sensing



- Coastal flights are performed weekly, April 1 to mid-May, then 6 days/week (weather permitting) through Labor Day. Barnegat Bay flights were added in 2008.
- After Labor Day, flights are performed once weekly through October.
- Sampling is initiated after multiple days of high chlorophyll *a* concentrations.
- Numerous blooms were targeted for sampling and identification.
- All data is available at www.state.nj.us/dep/bmw/

Algal Bloom Response (chlorophyll a)

June 3 through June 6, 2011

Friday - June 3, 2011

Saturday, June 4, 2011

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NJDEP and Rutgers University Chlorophyll Remote Sensing



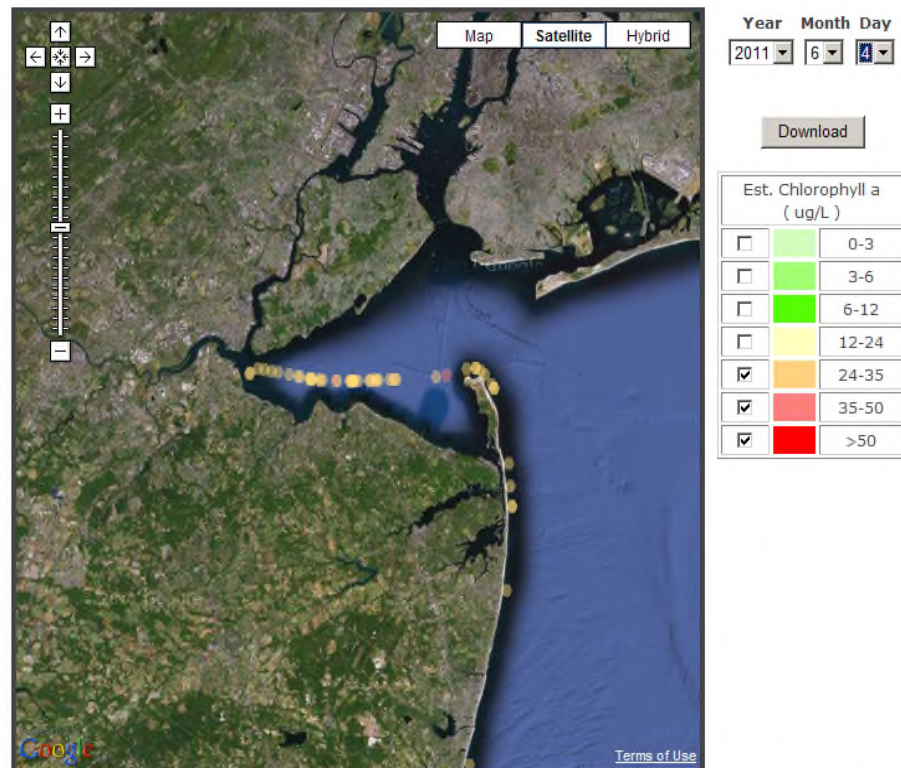
NJDEP's Bureau of Marine Water Monitoring has been working in cooperation with the NJ Forest Fire Service, Rutgers University, and USEPA Region 2 to implement aircraft remote sensing for estimating chlorophyll levels in NJ's coastal waters. Since chlorophyll is a plant pigment, high levels of chlorophyll in the water are typically associated with an algal bloom. The plane flies 6 days a week during the summer months, in favorable weather conditions, over the coastal waters of New Jersey. These flights provide a valuable perspective on water conditions and trends and enable the

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NJDEP and Rutgers University Chlorophyll Remote Sensing



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June 3 through June 6, 2011

Sunday – June 5, 2011

Monday, June 6, 2011

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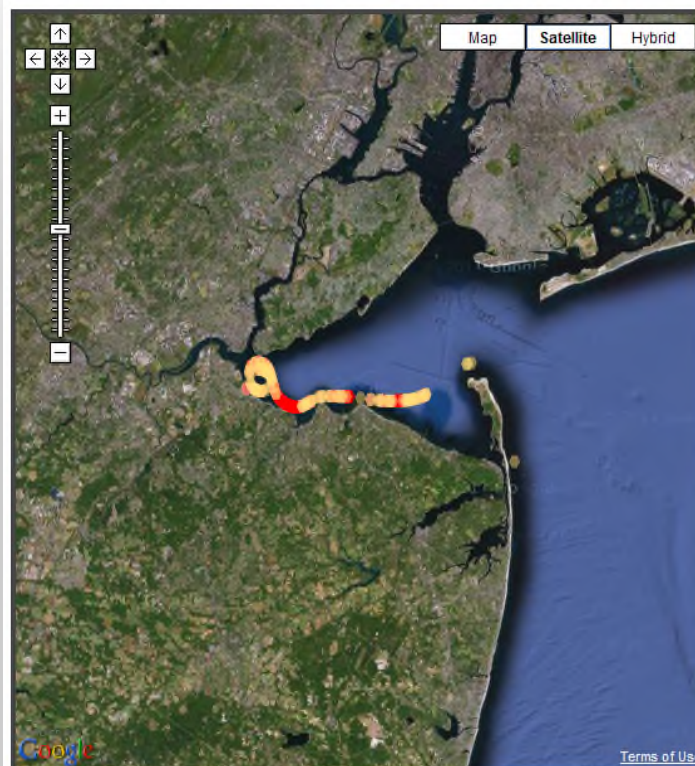
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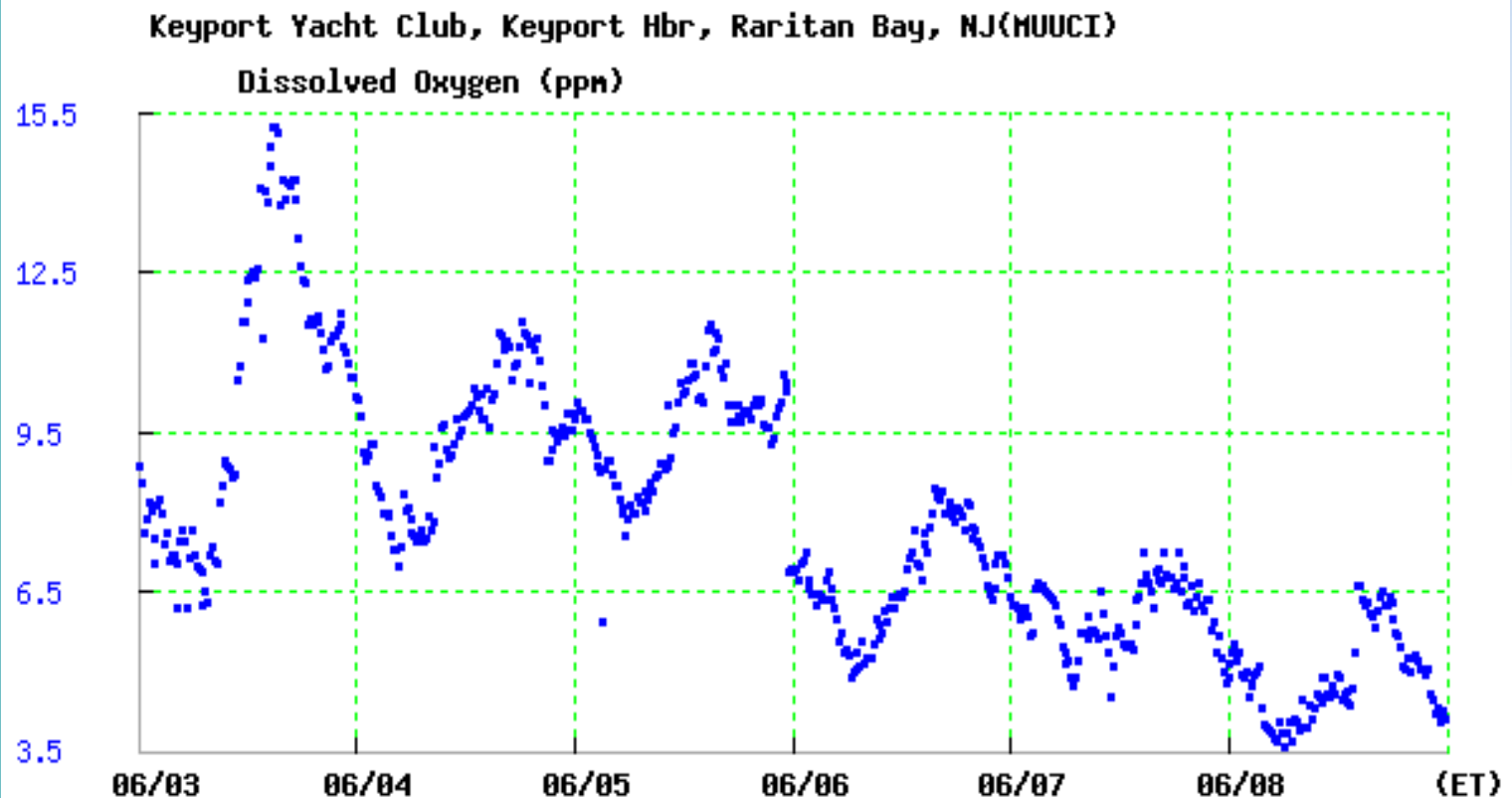
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Boat Sampling from Monday - June 6, 2011

- Bloom was most intense by Keyport Harbor area .
- *Heterocapsa rotundata* (~1.2 million cells/mL) identified as cause.
- *H. rotundata* is non-toxic dinoflagellate known to bloom in late spring and cause the water to appear reddish in color.

Keyport
Harbor
DO
Continuous
Monitoring
Data

Monmouth
University



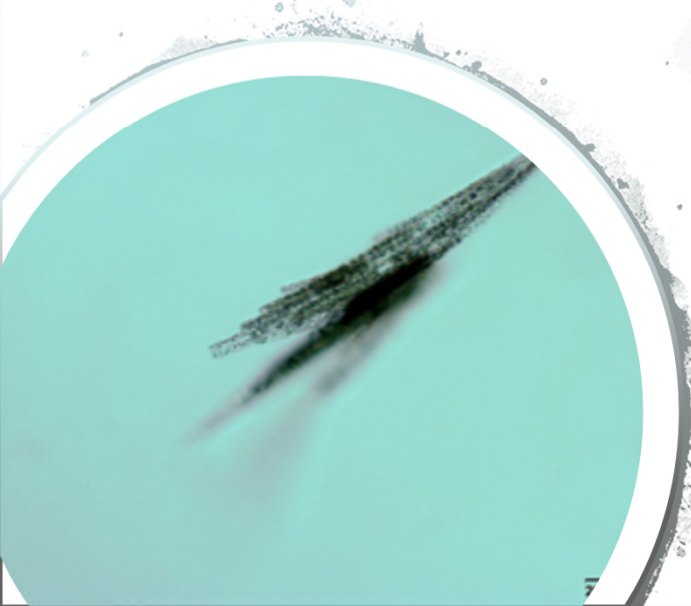
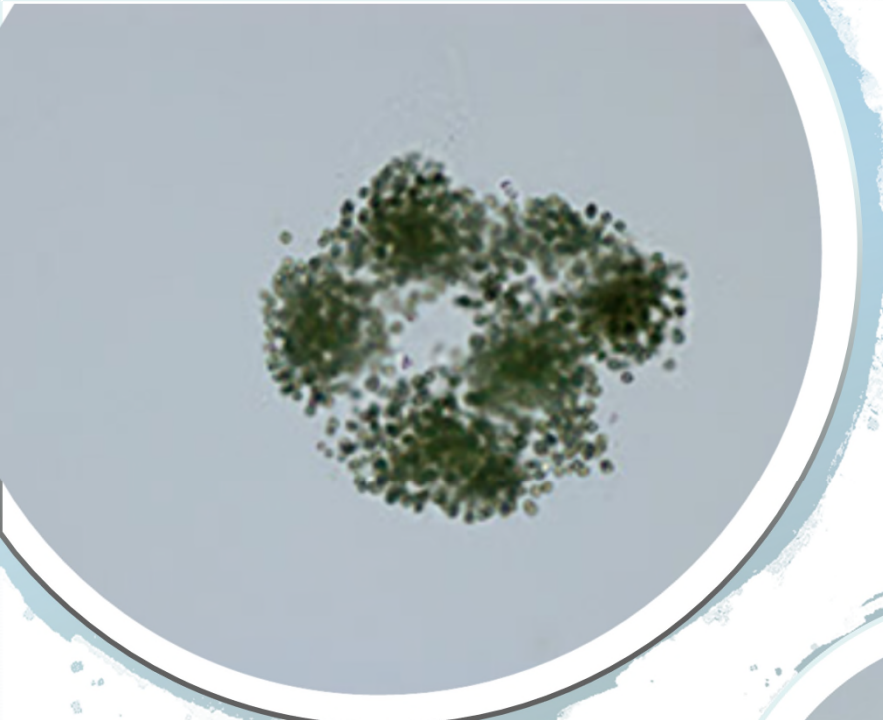
Fish Kill Reported - June 8, 2011



Juvenile Atlantic Menhaden in Keyport Harbor area

How Remote Sensing can Enhance Freshwater Monitoring

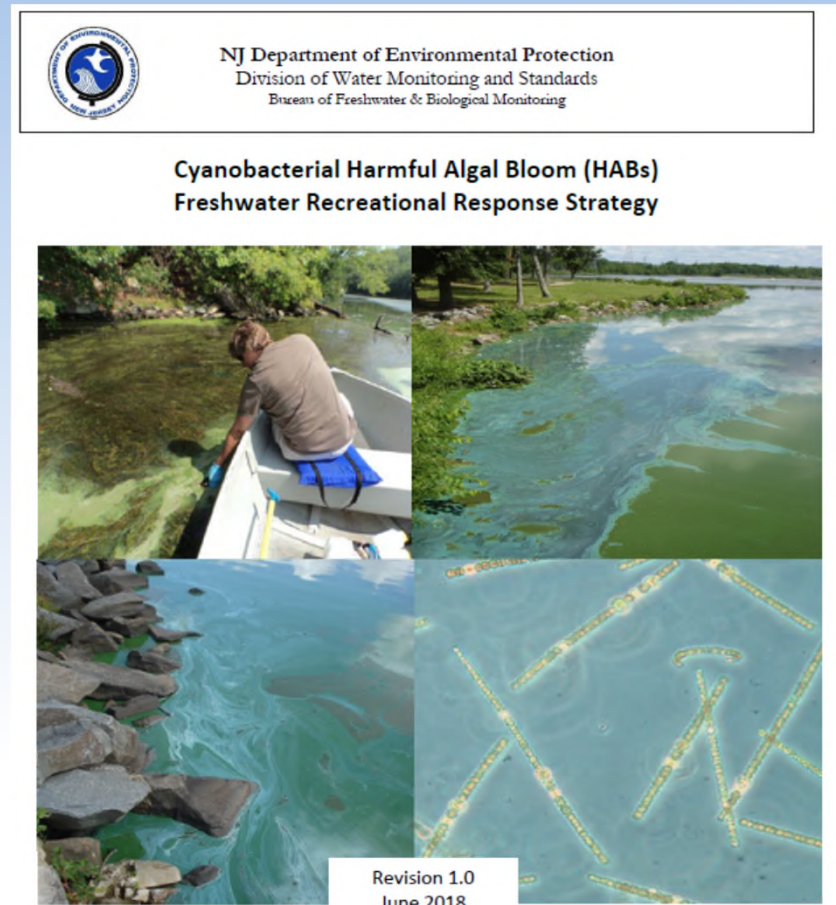
- Quicker response to algal blooms.
- Identify target areas for species identification and analyses.
- Monitor the status, intensity and location of the algal bloom.
- Alert officials and public of the potential for contamination of drinking water sources and recreational advisories.



Cyanobacterial Harmful Algal Blooms (HABs) Freshwater Recreational Response Strategy

Monitoring & Response Component

- Field screening and visual surveillance (strip test, phycocyanin)
- Laboratory
 - Species ID
 - Cell counts
 - Toxin analysis – ELISA (enzyme-linked immunosorbent assay) with CAAS - Cyanotoxin Automated Assay System



<https://www.state.nj.us/dep/wms/bfbm/download/NJHABResponseStrategy.pdf>

Remote Sensing of Freshwater HABs

- Pilot lakes sampled in 2017, 2 lakes in 2018
- Analyzed for multiple parameters
- Measured irradiance from lakes by aircraft (multiple wavelengths from literature)
- Correlate irradiance and water quality to cyanobacteria blooms

Algorithms for detecting phycocyanin

Name	Reference	Model
DE93	Dekker [16]	$PC \propto [(R_{rs}(600) + R_{rs}(648)) - R_{rs}(624)]$
SC00	Schalles & Yacobi [17]	$PC \propto R_{rs}(650)/R_{rs}(625)$
SI05	Simis <i>et al.</i> [10]*	$PC \propto R_{rs}(709)/R_{rs}(620)$
MI09	Mishra <i>et al.</i> [5]	$PC \propto R_{rs}(700)/R_{rs}(600)$
SM12	Mishra [29]	$PC \propto R_{rs}(709)/R_{rs}(600)$
MM09	Modified Mishra <i>et al.</i> [5]**	$PC \propto R_{rs}(724)/R_{rs}(600)$
HU10	Hunter <i>et al.</i> [11]	$PC \propto [(R_{rs}^{-1}(615) - R_{rs}^{-1}(600)) \cdot R_{rs}(725)]$

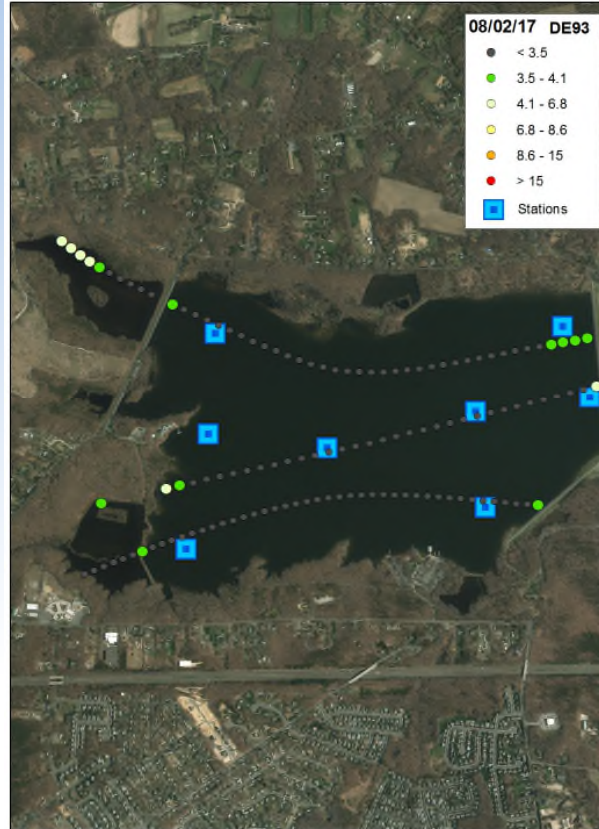
Ogashawara; Mishra; Mishra; Curtarelli; Stech. A Performance Review of Reflectance Based Algorithms for Predicting Phycocyanin Concentrations in Inland Waters. *Remote Sensing*. **2013**, 5, 4774-4798.

Results of Phycocyanin Detection (DE93 Model)

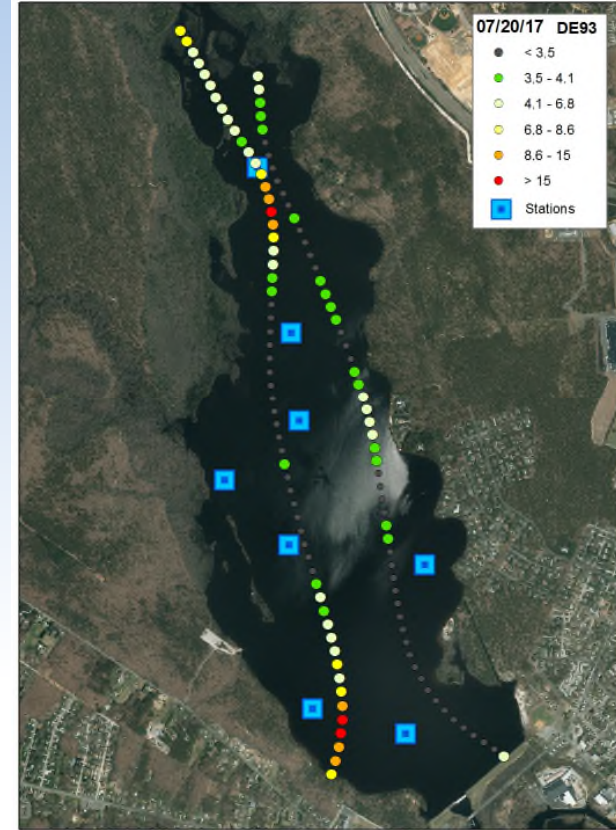
Deal Lake



Manasquan Reservoir



Union Lake



Sensefly eBee Plus Unmanned Aerial Vehicle



Summary

- Established remote sensing of chlorophyll 'a' along the NJ coast
- Developing remote sensing of phycocyanin for freshwater
- Continue data collection from Deal Lake, Manasquan Reservoir in addition to Swartswood Lake
 - More flights to refine the range of phycocyanin detection
 - Adding phycocyanin concentrations and cell counts at flight locations will refine and confirm algorithm
- Ultimate goal is to use phycocyanin algorithm on UAV

Acknowledgements/QUESTIONS?

Bureau of Marine Water Monitoring

- Bob Schuster, Bureau Chief - Remote Sensing Project Manager
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- Eric Ernst, Environmental Specialist - Phycocyanin Method
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Bureau of Freshwater & Biological Monitoring

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